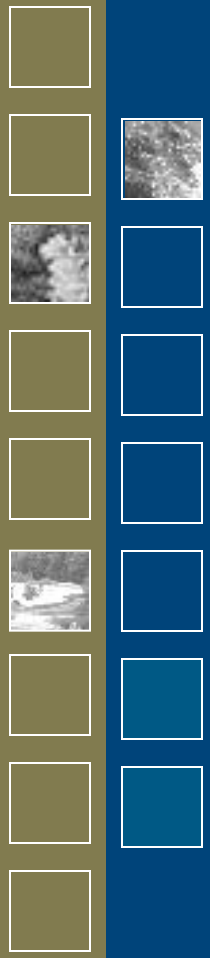

The Impact of Climate Change on Terrestrial Ecosystems

Climate Damages Workshop

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Washington, DC
January 28, 2011

Outline

- Background
- Descriptions of key ecosystem impacts
  - Vegetation distribution and dynamics
  - Wildfire dynamics
  - Species extinction risks
- Future research needs

Background

- Why do ecosystems matter when assessing economic impacts of climate change?
- Provide critical services to people
  - Provisioning (e.g., food, water, raw materials)
  - Regulating (e.g., air quality, storm protection, waste assimilation)
  - Cultural (e.g., recreation, passive use)
- These services have substantial economic value

Background (cont.)

- Climate change affects:
  - What species are where
  - How productive an ecosystem is
  - Rates of ecosystem processes (e.g., decomposition, denitrification)
  - The disturbance regimes it experiences
    - Drought
    - Fire
    - Pest outbreaks

Photo credits: USFWS

Background (cont.)

- Which ecological impacts?
- Given focus on use in integrated assessment models, focus on impacts:
  - Ecologically important
    - Impact is large and relatively widespread
  - Economically important
    - Impact will affect ecosystem services with high values
  - Well understood
    - Need to quantify projected impacts in scientifically robust way

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Key Ecosystem Impacts

- For each impact, will discuss:
  - Why the impact is likely to occur
  - The tools available to estimate the impact
  - What research has shown
  - Key uncertainties or other shortcomings with projecting future impacts
  - What key services are likely to be affected

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Changes in Vegetation

- How will climate affect vegetation?
  - Changes in temperature, precipitation, relative humidity affect:
    - What species can live where
    - Ecosystem productivity
    - Wildfire frequency and intensity, a key disturbance agent
  - Will fundamentally alter our environment – where grasslands and forests are, and what kinds of animals we see in different areas (not static)

Changes in Vegetation (cont.)

- Projecting future vegetation dynamics
  - Dynamic global vegetation models (DGVMs)
    - Large scale patterns of vegetation change
    - Typically have interacting modules:
      - Biogeography model – potential vegetation given climate and soil parameters
      - Biogeochemistry model, which simulates the movement of nutrients
      - Fire model – disturbance by wildfire

Changes in Vegetation (cont.)

- Projecting future vegetation dynamics (cont.)
  - For specified time period and climate scenario, DGVMs can tell you:
    - Potential vegetation type (e.g., temperate deciduous forest, temperate mixed forest)
    - Plant biomass (by life form – trees, shrubs, grasses)
    - Carbon storage (above and below-ground)
    - Burned area/wildfire frequency

Changes in Vegetation (cont.)

- Projecting future vegetation dynamics (cont.)
  - Many DGVMs are available; commonly used:
    - MC1 – United States
    - Lund-Potsdam-Jena (LPJ) – Germany/Sweden
    - SDGVM – United Kingdom
    - Integrated Biosphere Simulator (IBIS) – United States

Changes in Vegetation (cont.)

- What research has shown

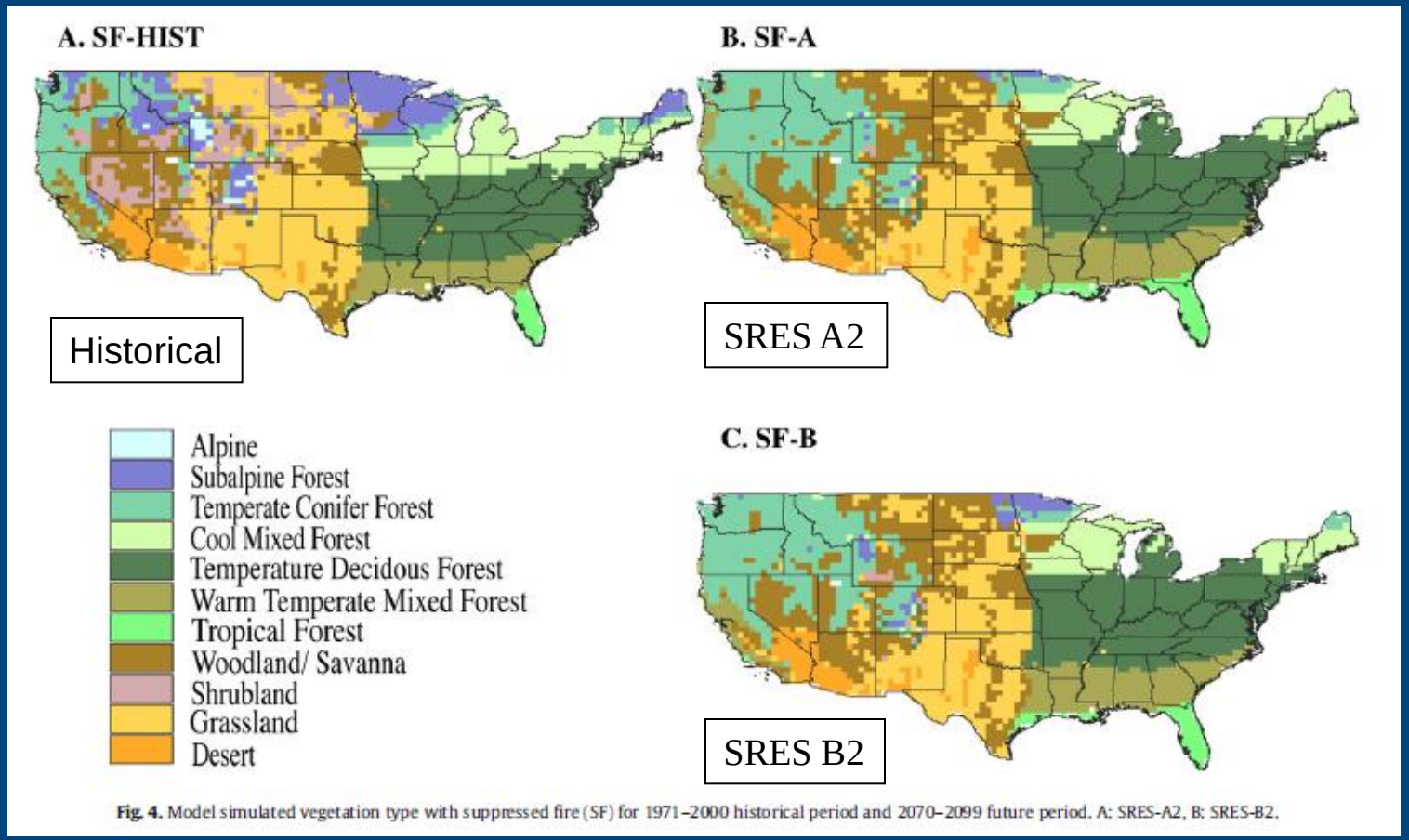
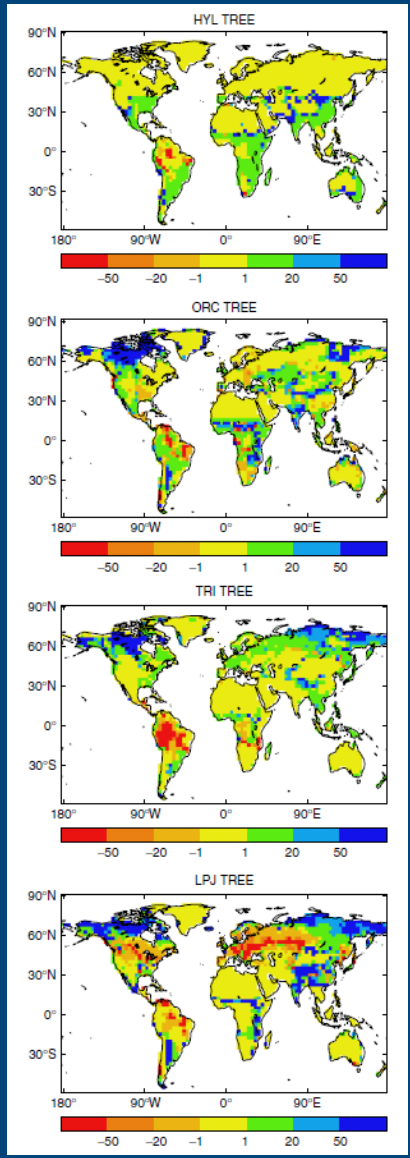


Fig. 4. Model simulated vegetation type with suppressed fire (SF) for 1971–2000 historical period and 2070–2099 future period. A: SRES-A2, B: SRES-B2.

From: Lenihan et al., 2008. *Global and Planetary Change* 64:16–25.

Changes in Vegetation (cont.)

- What research has shown (cont.)
  - % change in tree coverage, SRES A1FI, 4 DGVMs, Hadley GCM
  - Significant variability across models
  - Some areas of general agreement
    - Varying degrees of Amazon forest dieback
    - Boreal forest expansion



From: Sitch et al., 2008. *Global Change Biology* 14:2015–2039.

Changes in Vegetation (cont.)

- Key uncertainties
  - *Potential* vegetation only – most anthropogenic factors ignored; some can be addressed
    - Fires suppression can be accounted for
    - Can screen out urban/agricultural lands
  - Assume no barriers to plant dispersal
  - Pests and pathogens are ignored
  - Significant differences across DGVMs for the same region and climate scenario

Changes in Vegetation (cont.)

- <u>Affected ecosystem services</u>
  - Forestry
    - Timber
    - Non-timber forest products
  - Grazing
    - Forage productivity in grasslands, shrublands, savannas, and forests
  - Carbon sequestration and storage

Changes in Vegetation (cont.)

- Take home
  - Ecosystems across the globe will be affected, so this is a key impact to consider
  - Can examine multiple scales – countries, regions, the globe
  - Linked to critical ecosystem services
  - Good models, but difficult to know which ones are most reliable
  - Highly dependent on the GCM used
  - Look for areas of agreement, perhaps average DGVM results when possible

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Wildfire Dynamics

Photo credit: USFWS

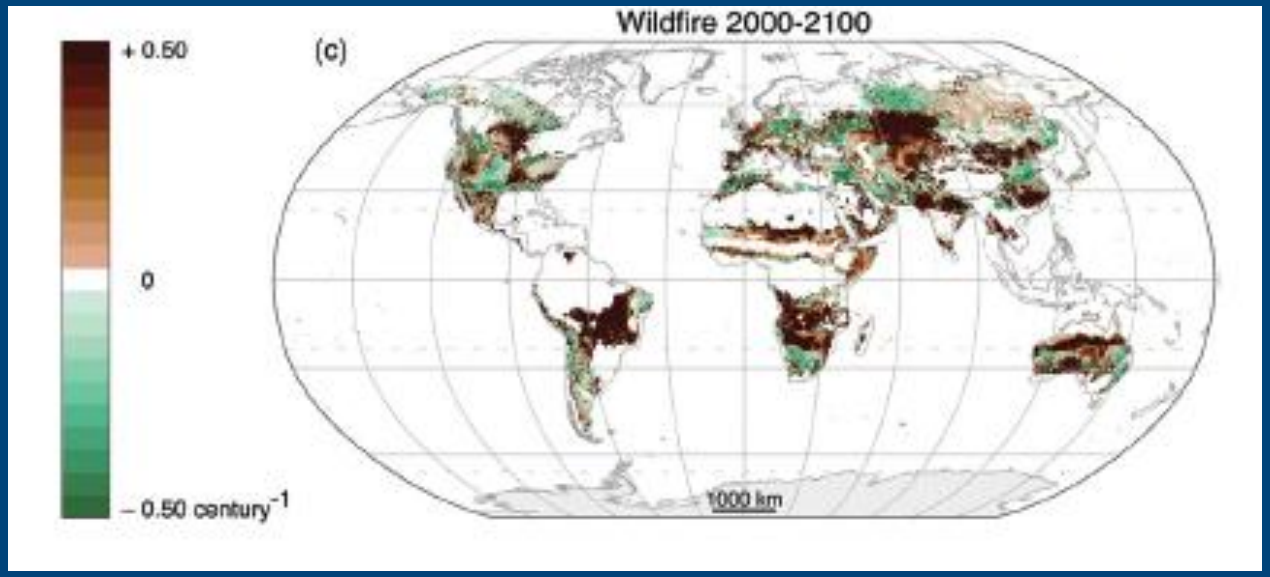
- How will climate affect wildfire?
  - Fires will likely increase in many areas via various mechanisms
    - Direct
      - Higher temperatures = more fires
      - Higher temperatures (and decreased precipitation) = desiccation of vegetation and forest floor (fuel)
    - Indirect
      - Changes in vegetation type (grassland/forest)
      - Changes in productivity (fuel load)

Wildfire Dynamics (cont.)

- Projecting future wildfire dynamics
  - Statistical models
    - Examine past fire behavior
    - Identify factors (e.g., via stepwise linear regression) that are key to predicting fire
    - Use equation to predict fires in future (based on key variables)
  - DGVMs

Wildfire dynamics (cont.)

- What research has shown
  - Change wildfire freq. from 2000-2100, A1B
  - More fire: U.S., central South America, southern Africa, western China, Australia
  - Less fire: northern Canada, northern Russia



From: Gonzales et al. 2010. *Global Ecol. Biogeogr.* 19: 755-768

Wildfire Dynamics (cont.)

- Key uncertainties
  - For both statistical model and DGVM approaches
    - Methods only roughly approximate historical fires
    - Thus, provide similarly rough estimates of future wildfire dynamics
    - Timing/locations of specific fires cannot be predicted

Wildfire Dynamics (cont.)

- Affected ecosystem services
  - Timber/non-timber forest product provisioning
  - Recreation
  - Fire suppression (not an ecosystem service but a real cost)
  - Regulation of air quality – aerosols (see Spracklen et al., 2009, *Journal of Geophysical Research*)

Photo credit: USFWS

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Species Extinctions

- How will climate affect it?
  - Climate (temperature/precipitation) is a key driver of species and ecosystem distributions
  - As climate shifts, areas that support specific species may move (sometimes into areas inhabited by humans)
  - Habitat may disappear (e.g., alpine, cloud-forest dependent species)
  - These dynamics will likely increase the risk of species extinctions




Photo credits: USFWS

Species Extinctions (cont.)

- Projecting future species extinctions
  - Most commonly involves application of "climate envelope" models
    - Use current distributions of a species to construct its climatic requirements
    - Under future climate change, then determine where species could live
    - Use species-area relationships to project extinctions

Species Extinctions (cont.)

- What research has shown
  - Results vary
    - 9–52% of species will be “committed” to extinction by 2050 (Thomas et al., 2004)
    - 20–30% of plant and animal species at risk of extinction with increase of 2–3 C (IPCC, 2007)
    - 0–60% extinctions for different taxa/methodologies (Pereira et al., 2010)
  - Envelope model did no better than “null” models in predicting species occurrence (null = species ranges are randomly placed in region; Beal et al., 2010)

Species Extinctions (cont.)

- Key uncertainties
  - Great deal of uncertainty within and across studies and modeling methods
  - Climate envelope models
    - May overestimate extinctions
      - Species may be flexible climatically
      - Biotic interactions may be more important than climate
    - May underestimate extinctions
      - Dispersal may be limited by habitat fragmentation
      - Impacts of climate change may be amplified by land use change

Species Extinctions (cont.)

- Affected ecosystem services
  - Another key issue…
  - How do you value global biodiversity?
    - Could query public
      - Some species may matter more to the public, and ecologically, than others

Species Extinctions (cont.)

- Affected ecosystem services (cont.)
  - Values could be tied to specific species, or suites of species
    - A given tree may provide highly valued wood
    - Bird watching/wildlife viewing is valuable
  - But values not tied to global extinction risk – linked to species, suites of species, and/or specific locations

Species Extinctions (cont.)

- Take home
  - Climate change is a threat to species, and more extinctions are likely to occur
  - Range of estimates available for species extinction risk
  - Robustness of estimates highly contested
  - Link to ecosystem services and values difficult
  - Proceed with caution

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Photo credit: USFWS

Future research

- Integrating across approaches
  - Across all impacts, variety of methods available that provide different estimates of impact
  - Need to think carefully about how to integrate across studies/tools
    - Meta-analyses?
    - 'Ensemble means' of ecosystem impacts with different models?
    - Need to be done with different climate scenarios/GCMs
    - How can this be done practically?

Future research (cont.)

- Major Gaps
  - Need to develop large-scale, long term projections for changes in
    - Pest outbreaks
    - Interior wetland change/loss
  - Changes in snow pack dynamics
    - Large-scale impacts on freshwater/marine ecosystems
    - Implications for recreational values

Photo credit: USFWS

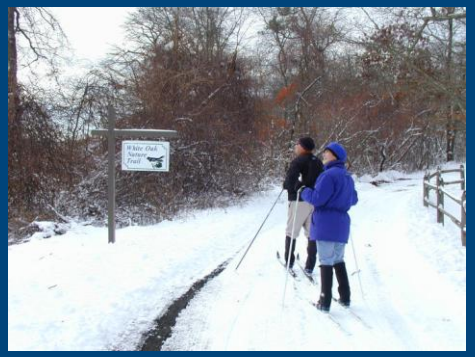
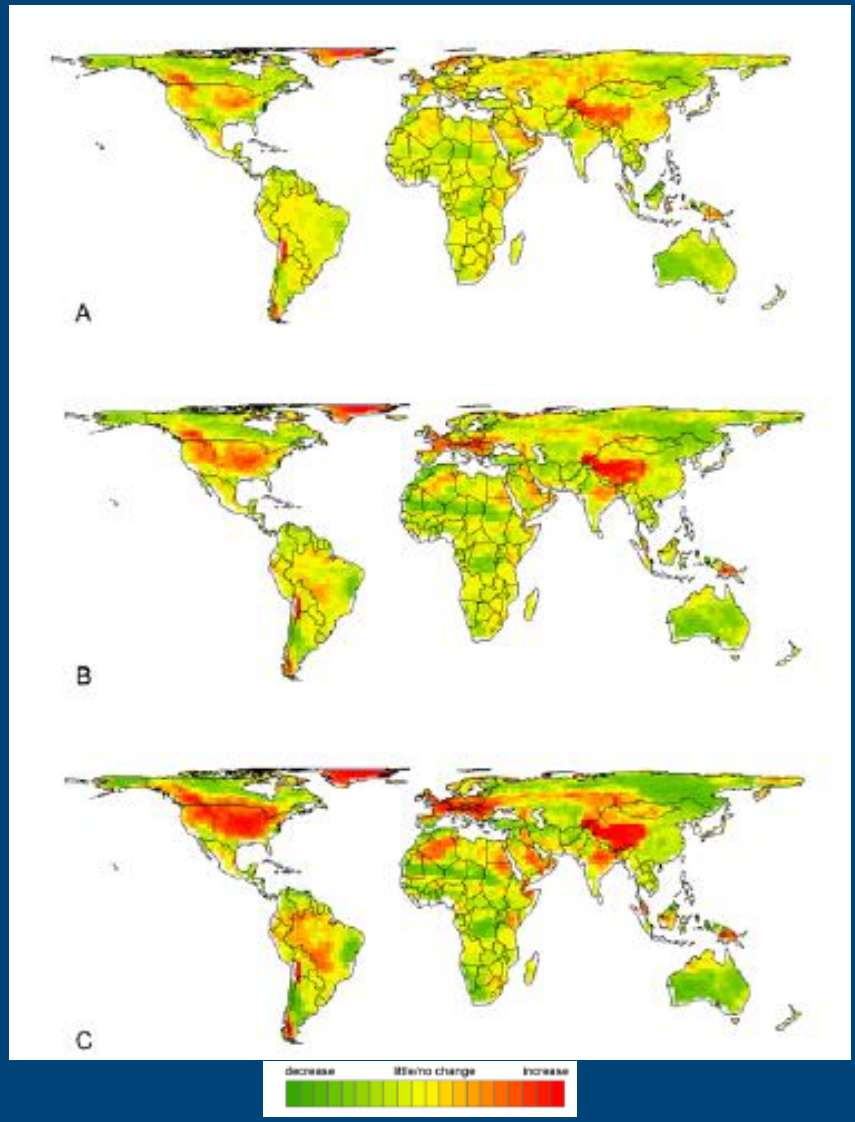


Photo credit: USFWS

Photo credit: USFWS

Wildfire Dynamics (cont.)

- What research has shown
  - Fire risk for three different time periods over 21st century
  - Higher fire risk:
    - U.S.
    - Amazon
    - Western China
  - Lower fire risk:
    - Northern Canada
    - Russia
    - Australia (?)



From: Krawchuck et al., 2009. *Plos One* 4: e5102.